



**Better Buildings Residential Network
Peer Exchange Call Series:
*Powered Up: Batteries and the Future of
Residential Energy Storage***

October 19, 2017

Call Slides and Discussion Summary

Agenda and Ground Rules

- Agenda Review and Ground Rules
- Opening Polls
- Residential Network Overview and Upcoming Call Schedule
- Featured Speakers:
 - **Ravi Manghani**, Director, Energy Storage, GTM Research
 - **Scott Averitt**, Technical Expert R&D Projects, Bosch
 - **Kent Walter**, Manager, Customer Technology Product Development, APS
- Discussion
- Closing Poll and Announcements

Ground Rules:

1. **Sales of services and commercial messages are not appropriate** during Peer Exchange Calls.
2. Calls are a safe place for discussion; **please do not attribute information to individuals** on the call.

Better Buildings Residential Network

Join the Network

Member Benefits:

- Recognition in media and publications
- Speaking opportunities
- Updates on latest trends
- Voluntary member initiatives
- Solution Center guided tours

Commitment:

- Members only need to provide *one number*: their organization's number of residential energy upgrades per year

Upcoming calls:

- November 2: [The Beatles, Beastie Boys, and Beyoncé: Messaging for Different Generations](#)
- November 9: [Money Down the Drain: The Energy-Water Nexus](#)
- November 16: [Wicked Smart: Optimizing Diagnostics through Home Energy Monitoring](#)
- November 30: [Solar Decathlon 2017: Winning Innovations in Efficiency, Health, and Water](#)

Peer Exchange Call summaries are posted on the Better Buildings [website](#) a few weeks after the call

For more information or to join, for no cost, email

bbresidentialnetwork@ee.doe.gov, or go to energy.gov/eere/bbrn & click Join

Best Practices: GTM Research

Ravi Manghani, Director, Energy Storage

Powered Up: Batteries and the Future of Residential Energy Storage

Prepared For:



Ravi Manghani
Director, Energy Storage

October 2017

gtmresearch
A Wood Mackenzie Business

Today's Residential Market Is Backup Power, But That's Still Pretty Big

3.5%

Share of U.S. Households
With Standby Generators

3.4 Million

Number of Existing
Residential Standby Units

~\$1 Billion

Annual Revenue From
Residential Standby Sales

Source: GTM Research

How Might The Economics of Residential Storage Pencil? Consider Salt River Project (Arizona) Residential Tariff

The Customer

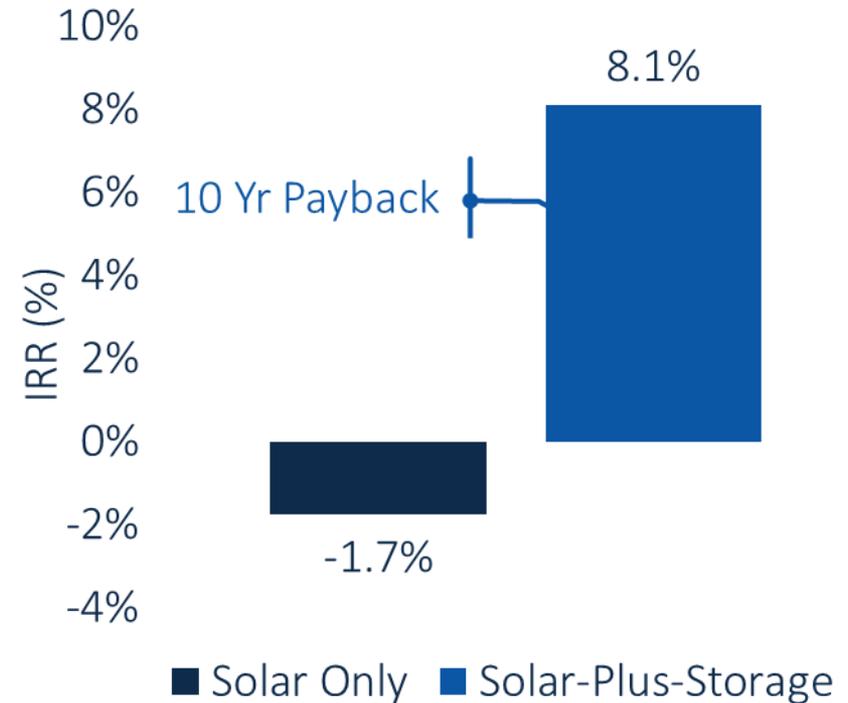
- Large Peak Load (20 kW)

The Tariff

- Energy Charge: \$0.039/kWh - \$0.063/kWh
- Demand Charge: \$3.41/kW - \$34.19/kW

The System (2016)

- Solar: 6 kW, \$3.05/W
- Storage: 4 kW/6 kWh, \$1,097/kWh



Source: GTM Research

Residential Value Streams – Stacking Encouraged

Backup Power

Demand Charge Management

Time-of-Use Arbitrage

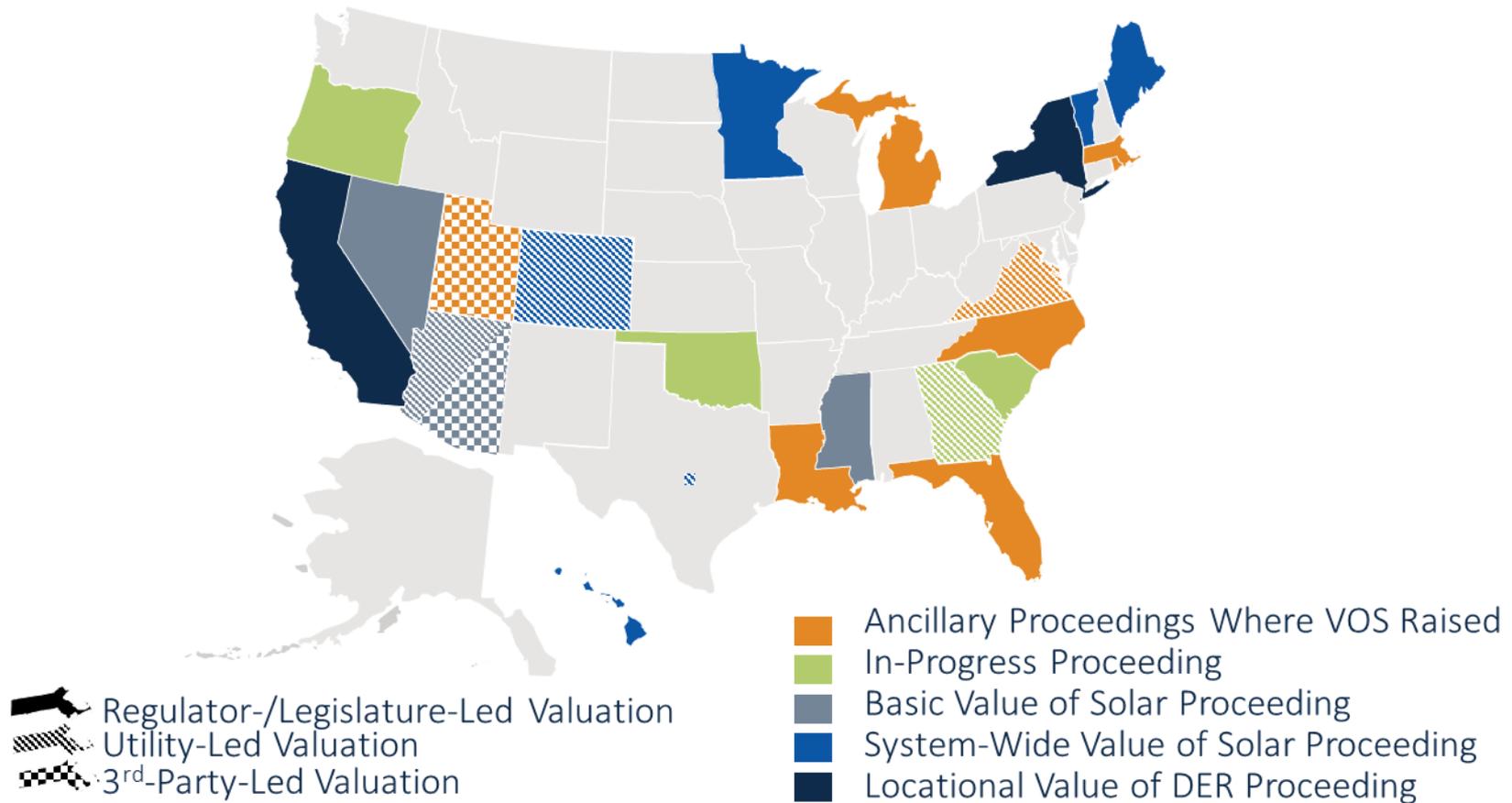
Solar Self-Consumption

Aggregation for Grid Services

Source: GTM Research

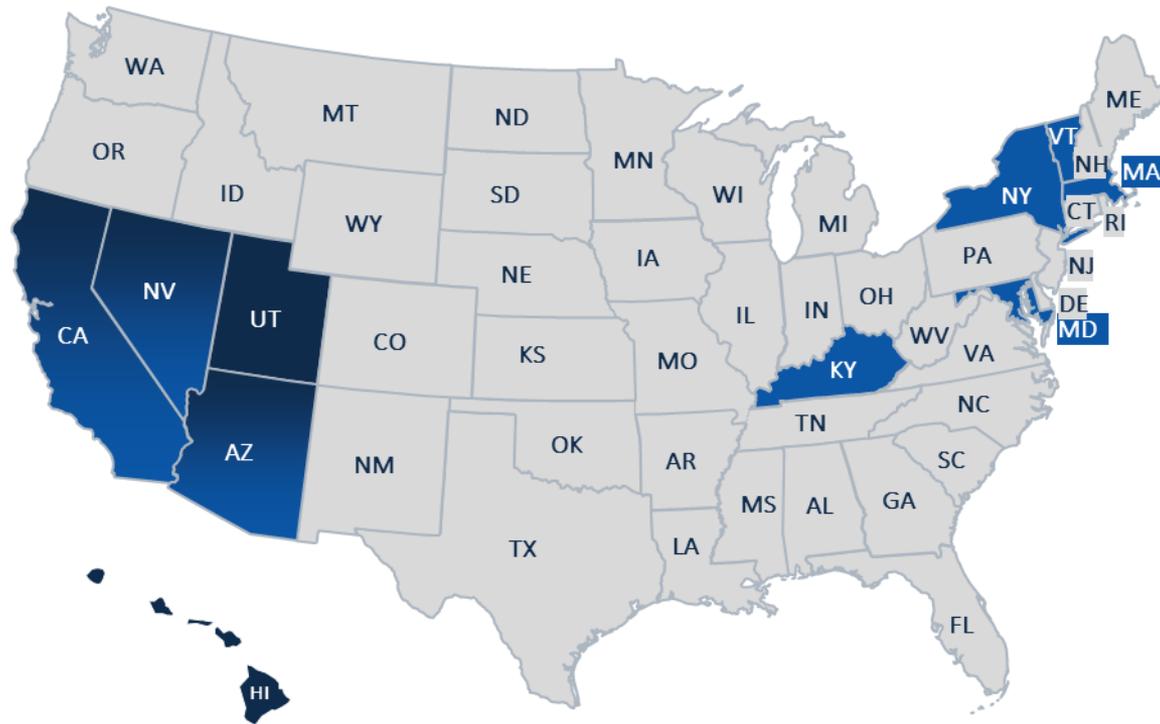
Value-of-Solar Studies in Regulatory Proceedings – First Step to Unlocking Value as Locational Distributed Energy Resource (DER)

Selected Complete and In-Progress Value of Solar (VOS) Proceedings/Studies



Source: GTM Research, Pace Energy & Climate Center.

Energy Storage Procurement Programs, Pilot Projects, and Incentives Build New Markets



Net Energy Metering/
Rate Reforms

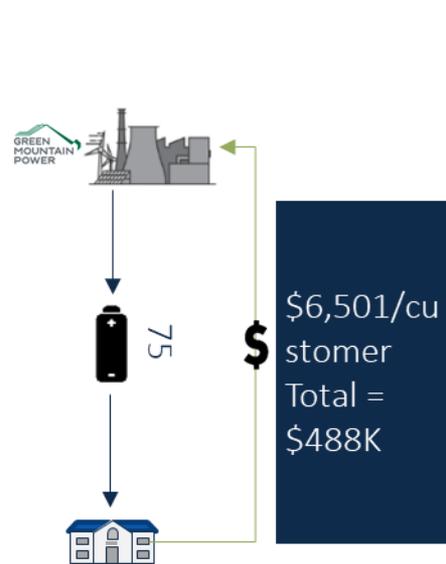
Grid Services Pilots,
Procurements,
and Incentives

- **Maryland** passed a storage incentive bill in May 2017
- **Massachusetts** set storage target in June 2017 and is working to add a storage incentive to its SMART solar program
- **Nevada** moved forward storage procurement and incentive bills in June 2017
- **Vermont** initiated the next phase of its Powerwall offerings and proposed a large scale solar-plus-storage project

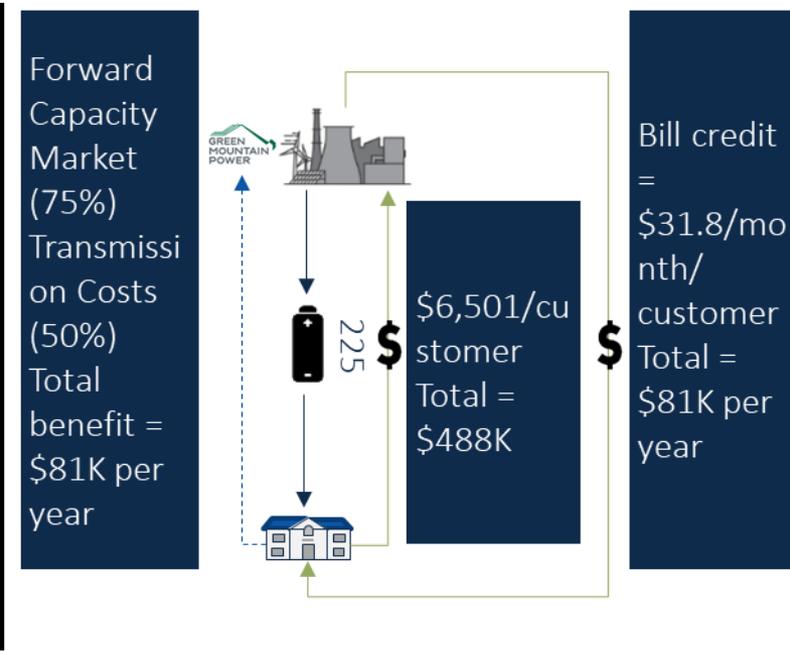
Source: GTM Research

Case Study: Green Mountain Power Uses Residential Storage to Reduce Peak Capacity and Transmission Costs

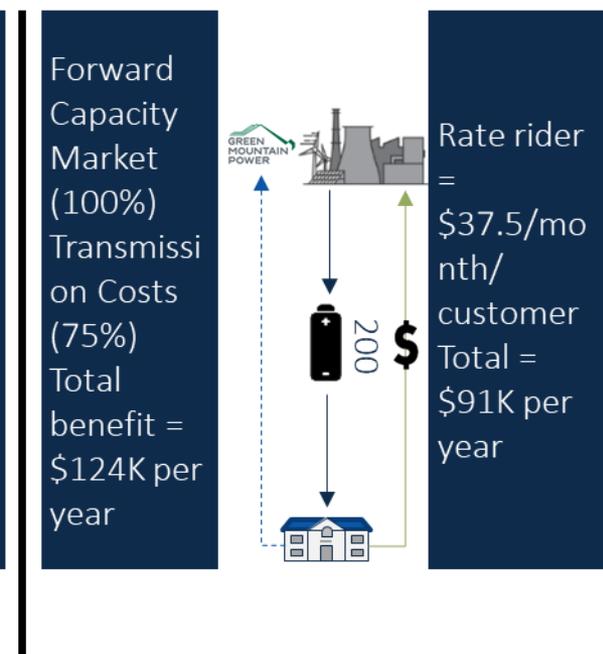
Option 1 (Direct Purchase)



Option 2 (Direct Purchase + Bill Credit)



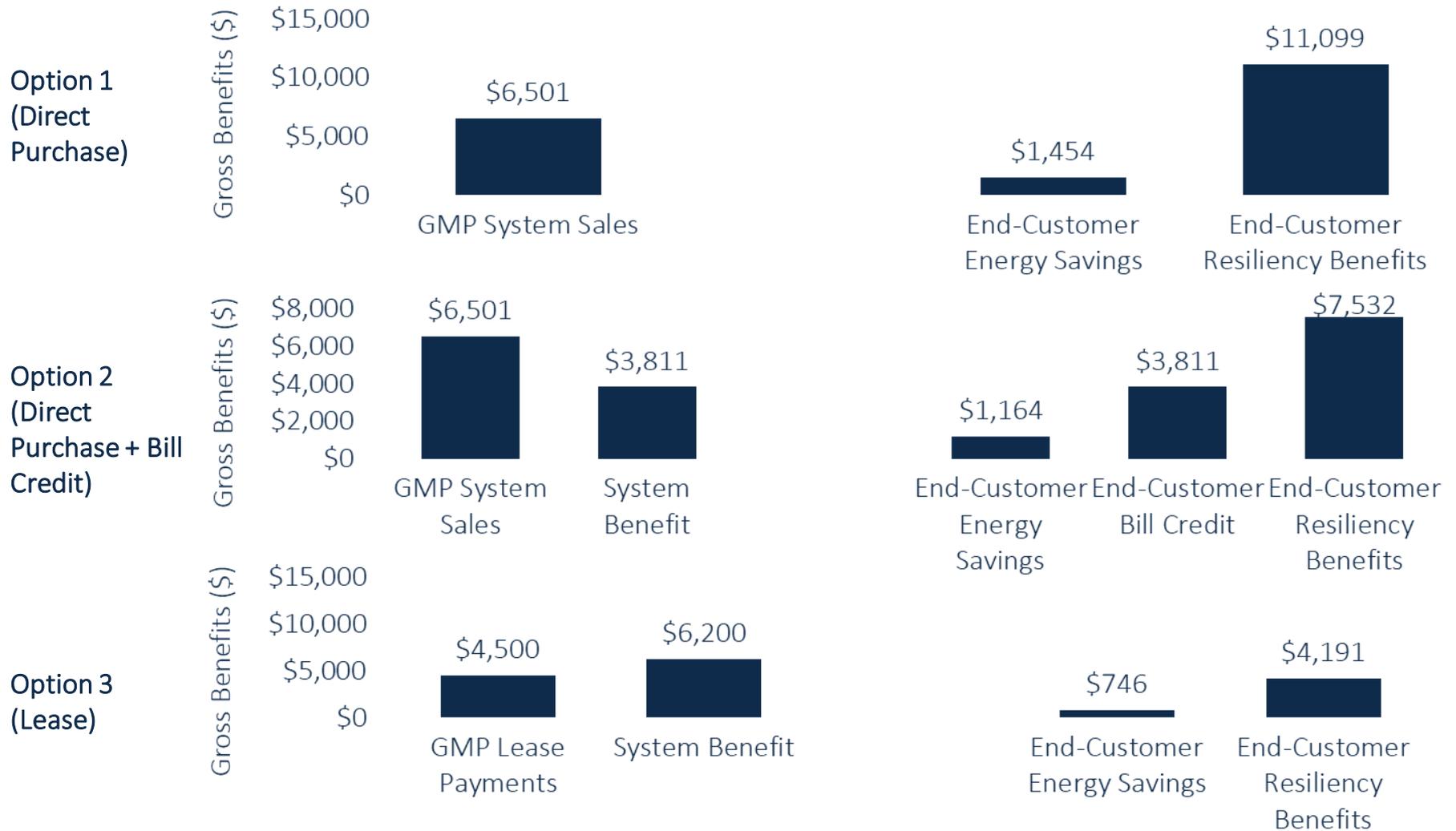
Option 3 (Lease)



Total Grid Services Benefits = \$205K per year

Source: Green Mountain Power, GTM Research

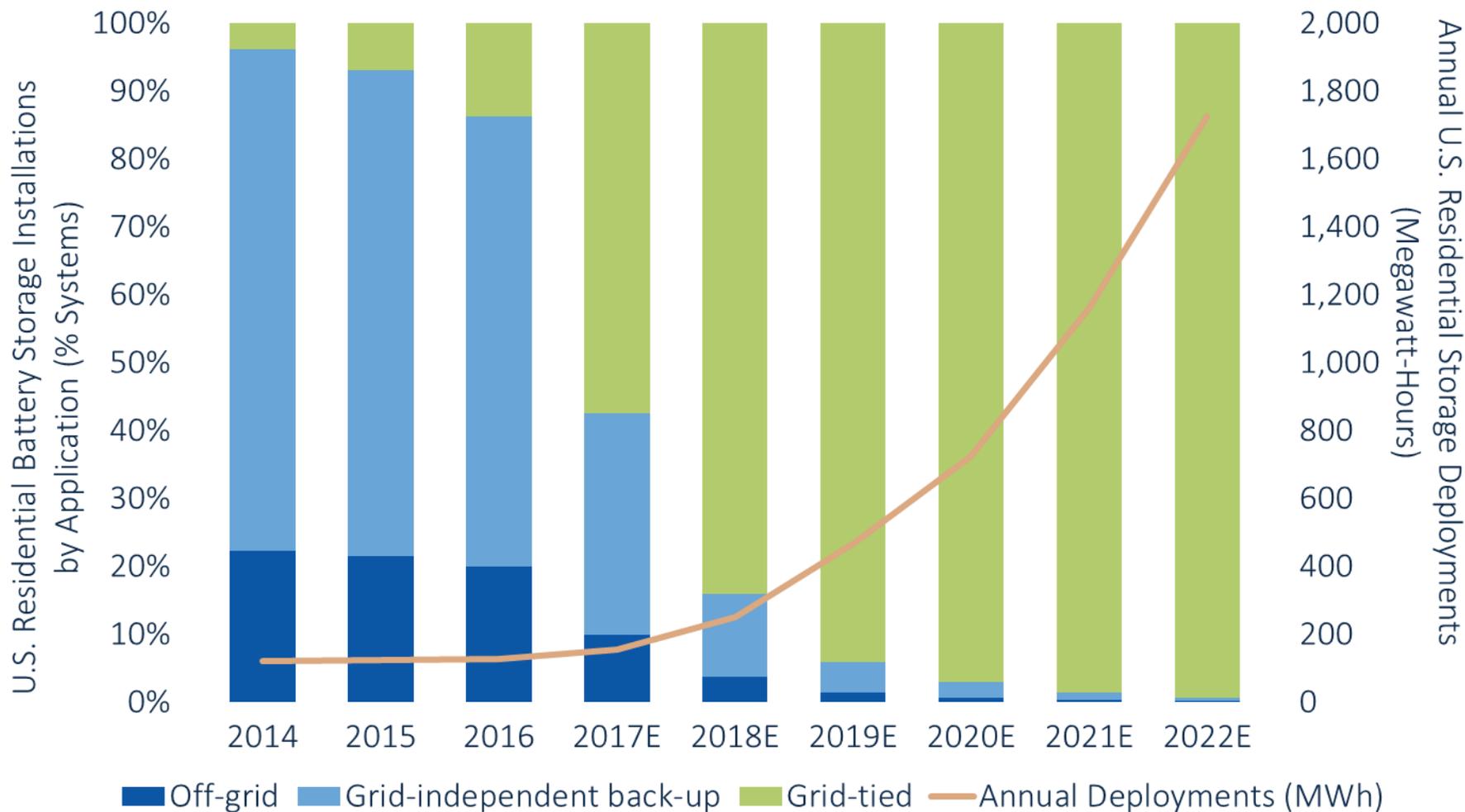
Case Study: Multiple Storage Value Streams – Green Mountain Power Innovative Pilot Project



Source: Green Mountain Power, GTM Research

U.S. Residential Storage Market Will Reach 1.7 GW by 2022

Grid-Tied Storage Becomes >90% in 2019



Source: GTM Research

Presentation Highlights: GTM Research

- **Solar-plus-storage makes good business sense in terms of:**
 - **Grid reliability:** Storage can be used to reduce demand charge.
 - **Cost-effectiveness:** Energy aggregation can support grid services that serve a large number of homeowners.
 - **Equity:** Solar storage can drive more equitable utility rates for both solar and non-solar homes.
- **Behind-the-meter, solar-plus-storage continues to grow:**
 - Green Mountain Power's pilot in Vermont gave homeowners the possibility to purchase or lease batteries to help lower peak energy costs and improve resiliency for homeowners. The 500 storage systems generate ~\$205K in annual grid savings.
- **Stacking up strategies brings the most value:** Solar-plus-storage paired with other energy-saving strategies (e.g., backup power, time-of-use arbitrage) can maximize energy efficiency and cost savings.

Best Practices: Bosch

Scott Averitt, Technical Expert R&D Projects

Home Energy Management System Project

Demand Response Balanced with Customer Comfort

Description

- ▶ Develop cyber-secure **Home Battery System** (HBS) controls that deliver high-reliability demand response while avoiding negative homeowner impacts.

Technologies

- ▶ Scalable system capable of utilizing Energy storage, connected home appliances, HVAC, rooftop PV, grid, etc. Designed to also work with EVs and wind.



Impact

- ▶ Enables standards for right-sizing home battery systems that is applicable to developers, appliance manufacturers, regulators and utilities nationwide as home automation is adopted.

Partners



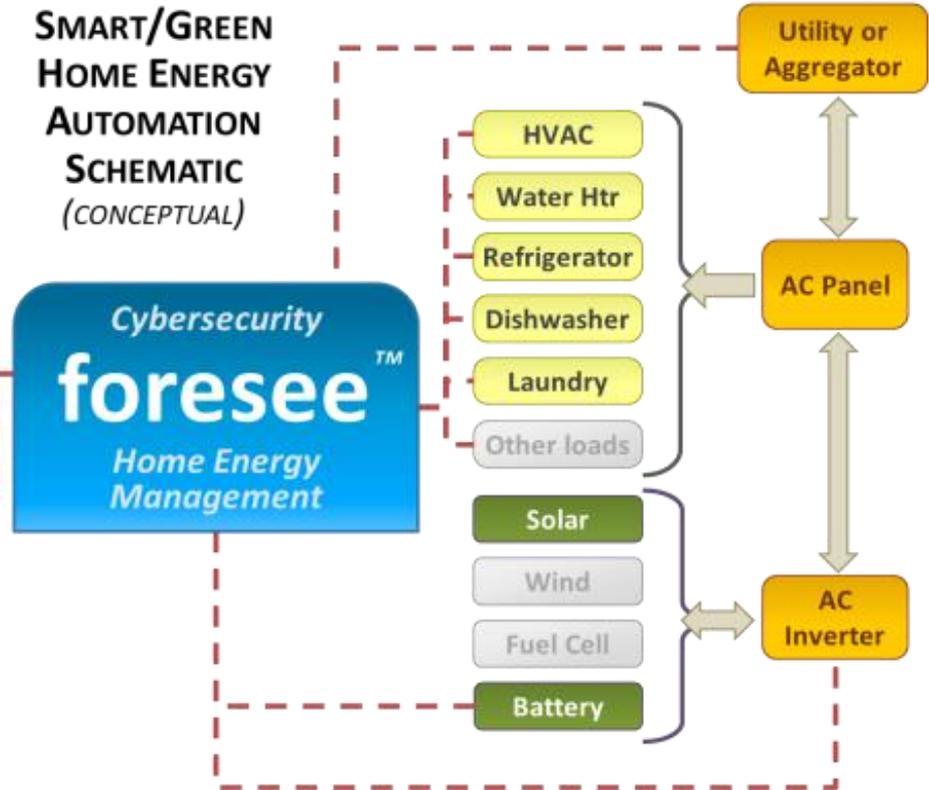
Home Energy Management System Project

Research hypothesis is that data-driven automation of connected residential equipment can achieve:

- ▶ Guaranteed comfort and improved energy savings for homeowners
- ▶ Optimal scheduling of home appliances based on user preferences and **Demand Response (DR)** requests
- ▶ Cybersecure DR delivered by **Critical Infrastructure Protection (CIP)** Cyber Security Standards compliant system
- ▶ Delivery of highly available (over 90%) and reliable DR capacity from individual homes
- ▶ Reliable DR capacity (over 5 kW/ home) prediction from individual homes across multiple planning horizons

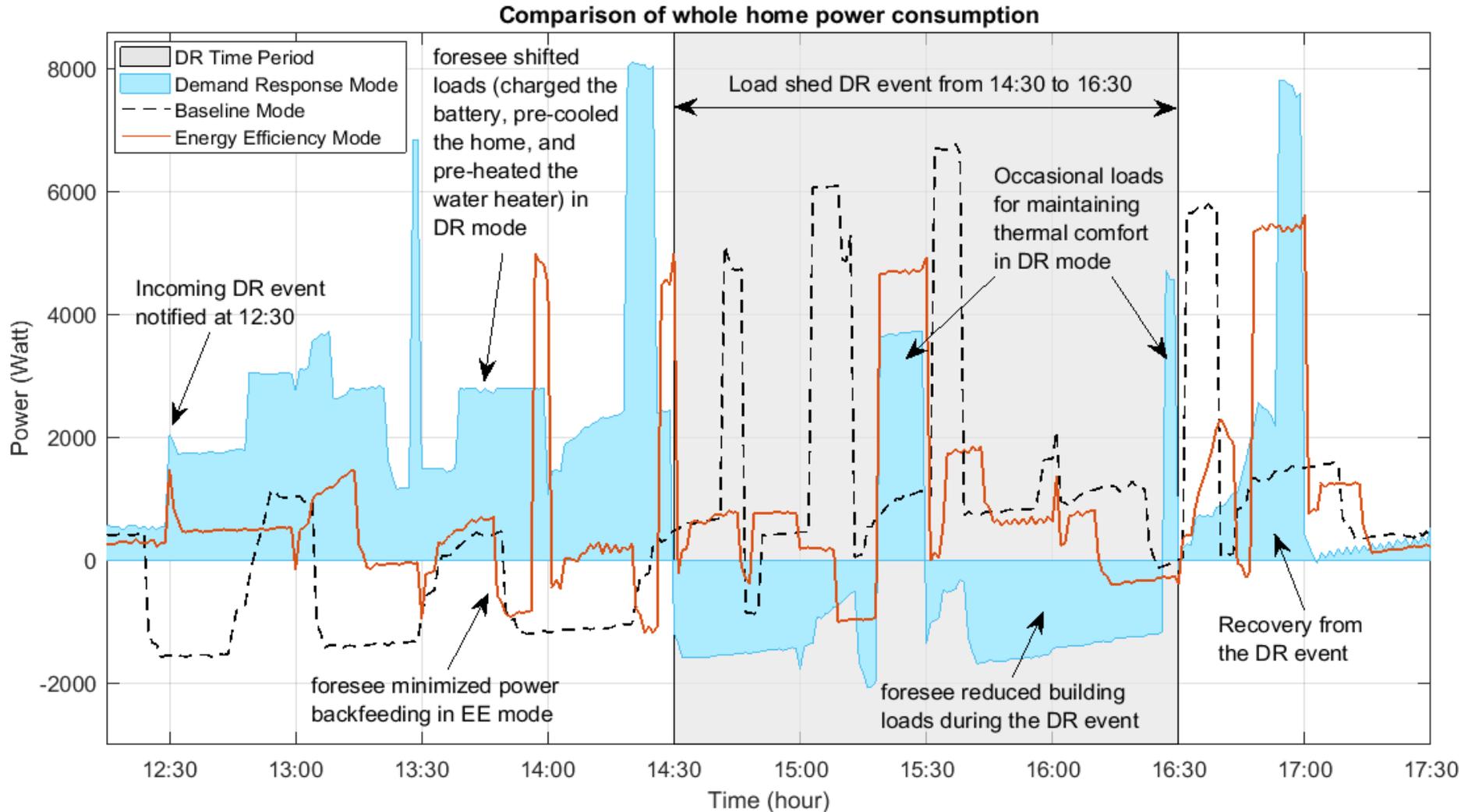
Home Energy Management System Project

foresee™ Home Energy Management System (HEMS) Schematic



Home Energy Management System Project

foresee™ Demand Response Use Case

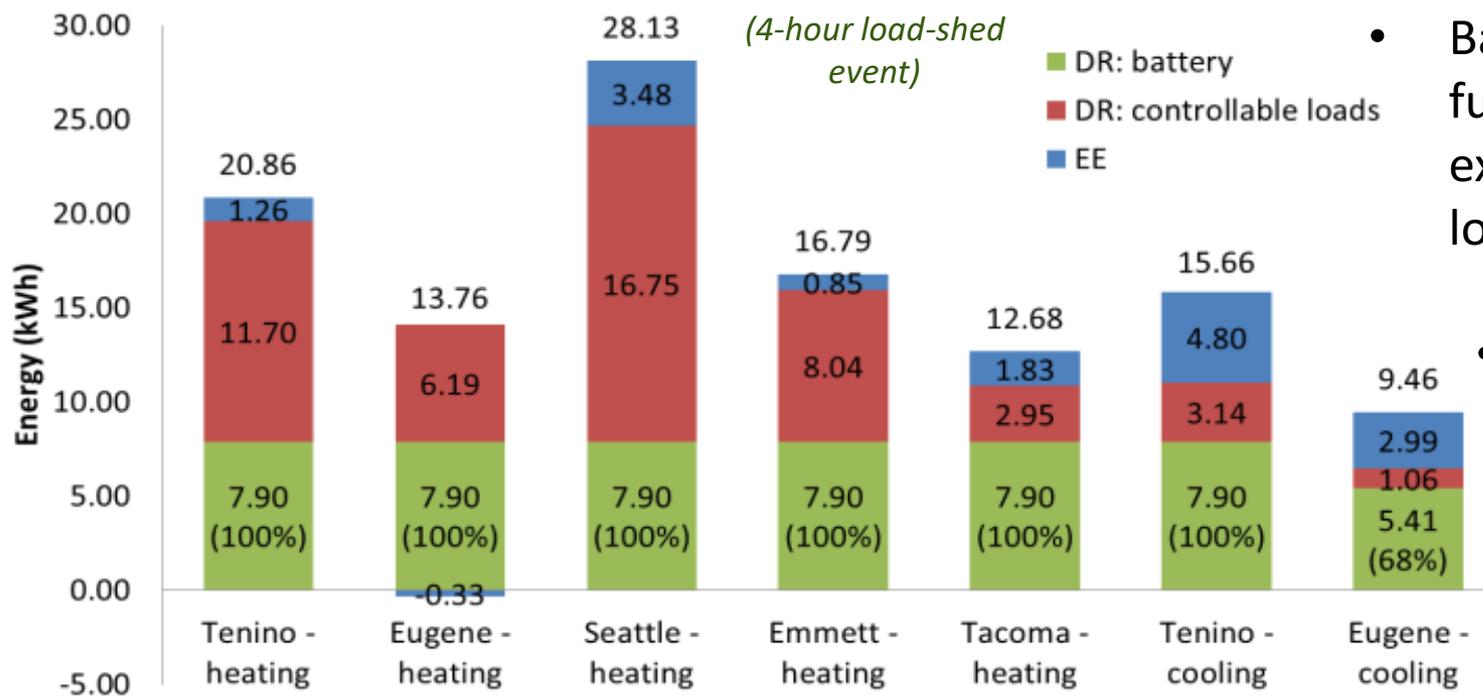


Unpublished preliminary laboratory results

Home Energy Management System Project

DR Load Reduction Breakdown by Source (DR vs. baseline)

Season	Heating					Cooling	
	Tenino	Eugene	Seattle	Emmett	Tacoma	Tenino	Eugene
RBSA*Home							
DR Forecast Error	8.08%	10.01%	2.10%	10.68%	-4.23%	9.29%	7.69%
DR Grid Energy Reduction (kWh)	20.86	13.76	28.13	16.79	12.68	15.66	9.46
DR Average Power Reduction (kW)	5.22	3.44	7.03	4.20	3.17	3.91	2.37



- Batteries were fully utilized except one low-load home

- Significant contribution from reduction of controllable loads

*RBSA is the NEEA Residential Building Stock Assessment

Home Energy Management System Project

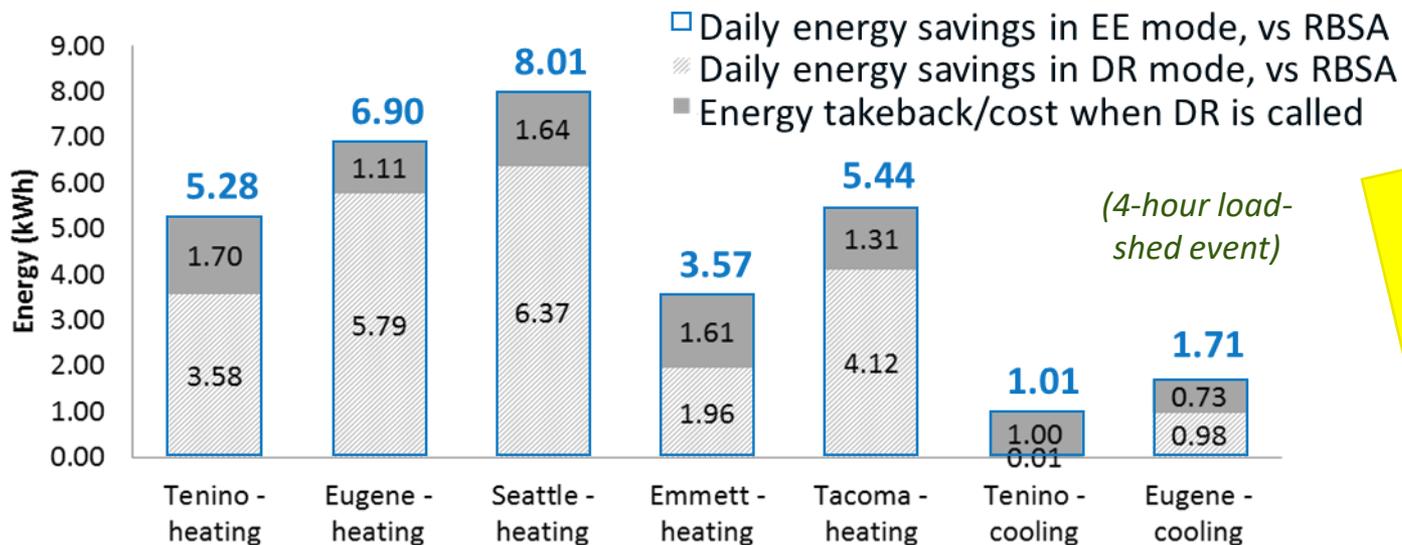
Daily Energy Savings Breakdown by Source

EE vs.
baseline

Season	Heating					Cooling	
RBSA Home	Tenino	Eugene	Seattle	Emmett	Tacoma	Tenino	Eugene
Daily Energy Savings (kWh)	5.28	6.90	8.01	3.57	5.44	1.01	1.71
Daily Cost Savings (\$)	0.58	0.76	0.88	0.39	0.60	0.11	0.19
Daily CO2 Reduction (lbs)	1.90	3.15	2.89	0.49	2.06	0.85	0.69

DR vs.
baseline

Season	Heating					Cooling	
RBSA Home	Tenino	Eugene	Seattle	Emmett	Tacoma	Tenino	Eugene
Daily Energy Savings (kWh)	3.58	5.79	6.37	1.96	4.12	0.01	0.28
Daily Cost Savings (\$)	0.39	0.64	0.70	0.22	0.45	0.00	0.11
Daily CO2 Reduction (lbs)	0.82	2.09	0.55	-0.27	0.66	0.76	0.53



2.1 kWh/day savings per home (5.5%) = 1 Quad annually

Home Energy Management System Project

Cybersecurity Implementation

- ✓ Documented rigorous risk assessment.
- ✓ Created an implementation plan to address risks in software, hardware, and system.
- ✓ Developed the cybersecurity layer based on the **North American Electric Reliability Corporation (NERC)** reliability standard for **Critical Infrastructure Protection (CIP)** Cybersecurity standards.
- ✓ Developed a security test plan and CIP compliance document
- ✓ Assessed platform hardening & documented best practices



Future Impact: Developing a journal paper to document, for the first time, how NERC CIP Standard requirements apply to end-use loads and building energy management systems, when aggregated to provide bulk-grid services.

Home Energy Management System Project

Current project runs through Q1 of 2018

- ✓ HEMS software + model development complete
- ✓ Cybersecurity implementation complete
- ✓ Hardware plus software integration completed at NREL
- ✓ Full operational validation complete

Next Steps

- ▶ Perform operational scenarios on test system (Grid, Climate, and Residence)
- ▶ Cybersecurity penetration testing
- ▶ Apply methodology to U.S. housing market opportunity space

Benefits

- ▶ Reliable DR aggregation to utilities
- ▶ Lower operating cost to homeowner
- ▶ Reduced energy & CO2 footprint
- ▶ Helps achieve Net Zero Energy + LEED ratings
- ▶ Competitive advantage for developers/builders
- ▶ Supports national goals for energy security and lower energy consumption



Utility Bill

Presentation Highlights: Bosch

- **Solar-plus-storage coupled with connected appliances can result in more predictive energy efficiency and demand response (DR):** The Home Energy Management System Project, with its battery storage system and self-learning adaptive controls, had the following benefits:
 - **No-pain DR experiences:** Energy storage provided homeowners constant energy throughout the day even during peak times.
 - **Reliable DR aggregation for utilities:** Each home generated ~2.1 kWh/day savings, which makes for 1 Quad aggregated savings annually.
 - **Increased interoperability:** The project used machine-learning to derive usage patterns and balance energy use with connected appliances.
- **Not overcharging or fully discharging are critical in keeping batteries healthy:** Batteries in the project were not used to 100% capacity, to maintain their longevity. The home battery storage provided the main portion of energy, the rest coming mostly from controllable loads.
- **Cybersecurity is key in battery storage, in order to protect data privacy and ensure grid security.**

Best Practices: APS

Kent Walter, Manager of Customer Technology
Product Development

Batteries and residential energy storage

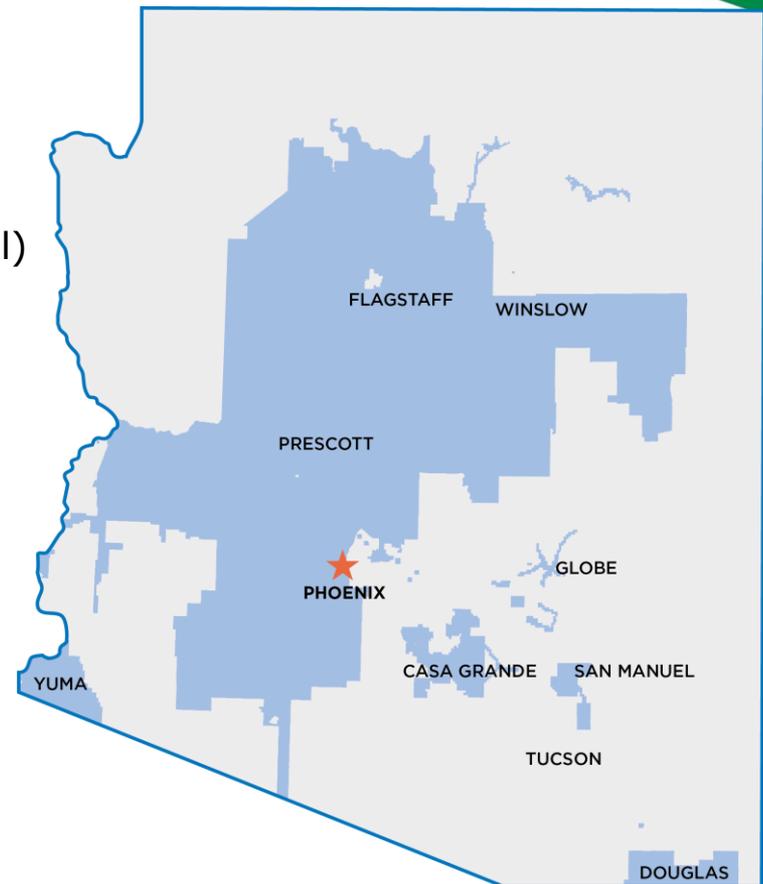
Kent Walter
Manager, Customer Technology Product
Development
10/19/2017



APS Service Territory

Arizona's largest and longest-serving utility
 – since 1886

- **Service Territory**
 - 11 of 15 counties
 - 1.2 million customer accounts (89% residential)
 - Approximately 45% of Phoenix customers
 - 34,646 square miles
- **Arizona's largest taxpayer**
 - \$3.4 billion annual economic impact to AZ
 - \$1 billion spent annually with AZ businesses
 - \$400 million with minority and women-owned businesses
- **Investor-owned utility—subject to forms of public control and regulation**
- **~6,300 employees**
- **Peak load ~7,400 MW in 2017**



APS Advanced Rates

- More than 50% of APS residential customers on Time Of Use (TOU) and TOU + Demand
 - Rates allow customers to capture value by managing their load, including demand
 - Encourages innovative technology adoption
- On-Peak period is weekdays from 3:00 pm to 8:00 pm excluding holidays
- Rates are seasonal, below rates reflect summer season:

Billing component	Determinate	saver choice	saver choice plus	saver choice max
Demand (kW)	Highest Hourly On-Peak Usage	\$ -	\$ 8.4000	\$ 17.4380
On-Peak (kWh)	Cumulative On-Peak Usage	\$ 0.2431	\$ 0.1316	\$ 0.0868
Off-Peak (kWh)	Cumulative Off-Peak Usage	\$ 0.1087	\$ 0.0780	\$ 0.0523

An Easy Simple Solution

Two ways to save is good.
Three ways is better.



\$100
Customer Bill



Two Ways to Save

- Using less energy
- Using power at off-peak times

\$100
Customer Bill



Three Ways to Save

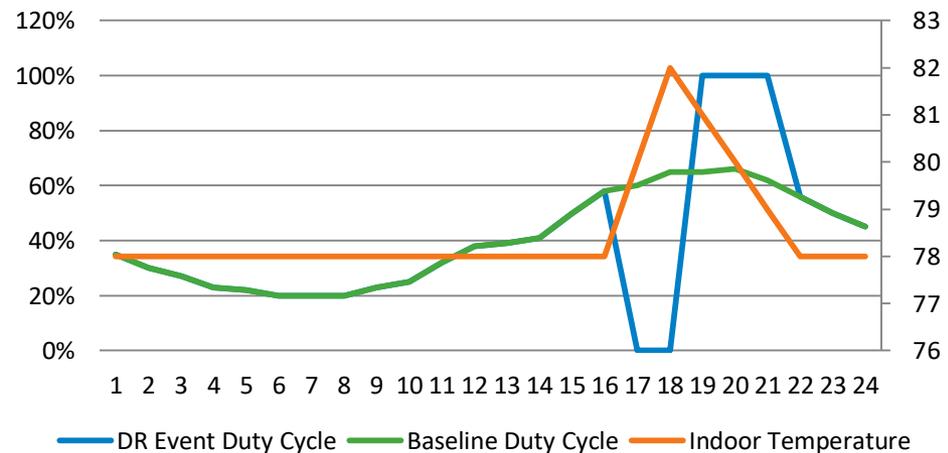
- Stagger use of major appliances
- Shift usage to off-peak times
- Save on overall energy use

Complexity of Advanced Rates and Demand Response (DR) programs

- Best to manage load with resources for monthly savings opportunities through savings on bill
- Program design is critical based on characteristics of technology

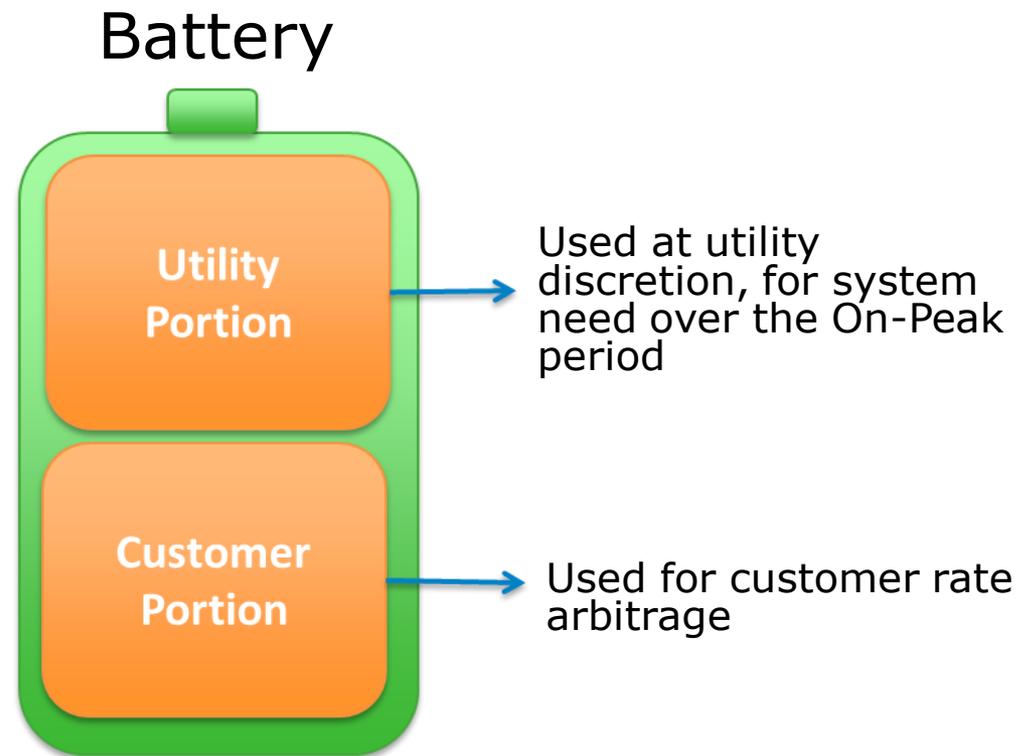
Traditional exercise of residential thermostat DR under advanced rates has potential to increase of AC Duty Cycle by 35%. An increased duty cycle could set a new customer demand which could impact customer bill absent thoughtful program design.

Summer AC Duty Cycle



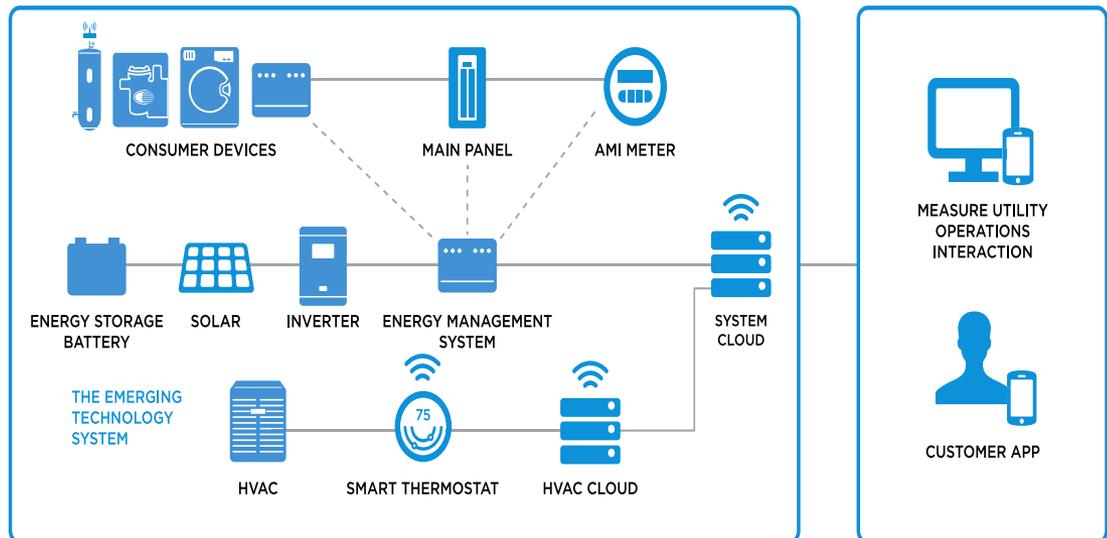
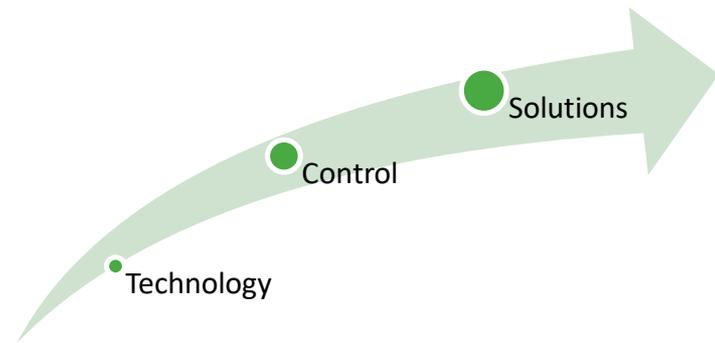
Batteries offer a unique opportunity for DR

- Customer ability to capture system value established through management of demand
- Direct utility engagement where other local needs may deviate from On-Peak needs
- Virtual firewalls (defined kWh) can alleviate somewhat unclear DR value proposition and measurement
- Separation of values ensure no sacrifice of customer savings from investment
- Unused utility portion of battery can serve customers as back-up power when available



Customer Storage Roadmap

- Solar Innovation Study
 - 10 batteries optimizing customer bill savings on advanced rates
 - Understand technology capable to optimize advanced rates
- APS Storage Rewards program
 - 40-90 residential batteries to be deployed in 2018
 - Develop joint use and control of battery technology



Presentation Highlights: APS

- **Synergies across multiple home energy management technologies can provide increased value for homeowners:**
 - By exploring technology interoperability in 75 homes with different cohorts of home energy management tools, including solar-plus-storage, the APS' Solar Innovation Study will give a better insight into the variety of mixes that can provide the greatest energy savings.
- **Shared battery use has benefits for homeowners and utilities:**
 - Through its 2018 Storage Rewards program, APS will deploy residential batteries to be jointly used by homeowners and utilities, which will reduce peak load and bring cost savings for both parties.
- **Utility-driven programs need to be carefully designed to prevent any unwanted side effects.**
 - Demand response (DR) with advanced rates can increase the air conditioner (AC) duty cycle by ~35%: an AC usually operates at ~65%, but when turned on after a DR event, it will start at 100% to get to the initial setpoint. In a state with high AC use like Arizona, this might mean increased energy use and costs for homeowners.

Discussion Highlights

- **Battery storage is still in testing stages**, and it will take time to scale this technology and make it cost-competitive with the traditional grid.
- **A larger solar-plus-storage market will drive down the costs of these systems in the future.**
 - The market is still relatively small at ~100 MW. Homeowners respond to price signals, so they'll need to see a reasonable payback to adopt this technology. The systems currently range from \$800/kWh to \$2,000/kWh.
- **Some changes in States' regulatory framework might need to happen to better promote adoption of solar-plus-storage.**
 - Independent System Operators (ISOs) might help drive this effort across the U.S.: California ISO is one example.
- **The first major adopters will likely be the areas with high utility rates or grid resiliency issues.**
 - Customer needs, for example, comfort, energy, and cost savings, will also drive solar-plus-storage adoption.

Upcoming Seasonal Messaging Opportunities

Now is the time to start planning energy efficiency messaging!

Dec 31 – Jan 1

New Year 

January 6

**National
Technology
Day**

January 10

**National Cut
Your Energy
Costs Day**

 Home Energy Audits Can Help You Keep That New Year's Resolution



U.S. Department of Energy

[Article: Home Energy Audits Can Help You Keep That New Year's Resolution](#)

Ready,
Set,
SAVE!



Set your thermostat as high as comfortably possible in the summer. The smaller the difference between the indoor and outdoor temperatures, the lower your overall cooling bill will be.

comoenergychallenge.com

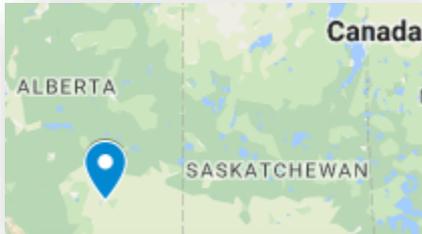
Brought to you by the CoMo Energy Challenge.
Competing for \$5 million and change.

City of Columbia, Missouri

[Facebook Post](#)

Addenda: Attendee Information and Poll Results

Call Attendee Locations



Call Attendees: Network Members

- Advanced Energy
- Boulder County
- California Energy Commission
- Center for Energy and Environment
- Center for Sustainable Energy
- City of Chula Vista Conservation Section
- City of Fort Collins
- CLEAResult
- Efficiency Maine
- Efficiency Nova Scotia
- EnergyWize
- FMC Facility Management Consultores
- Focus on Energy
- Fort Collins Utilities
- FSL Home Improvements
- Home Energy Analytics, Inc.
- International Center for Appropriate and Sustainable Technology (ICAST)
- La Plata Electric Association
- Northeast Energy Efficiency Partnerships (NEEP)
- Pratt Center for Community Development
- Ryan Taylor Architects, LLC
- The Insulation Man, LLC
- TRC Energy Services
- Wisconsin Energy Conservation Corporation (WECC)

Call Attendees: Non-Members (1 of 3)

- Arizona Public Service (APS)
- BAE Systems
- Ballarat Consulting
- Benningfield Group
- Blue Ridge Energy
- Bosch
- California Public Utilities Commission
- Canadian Home Builders' Association (CHBA)
- Carolina Smart Homes
- Celtic Energy Inc
- City of Mount Vernon, IL
- Codman Square Neighborhood Development Corporation
- Community Housing Partners
- Compass Solar Energy
- County of Santa Barbara
- Danfoss
- De Young Properties
- Dimension Energétique
- E4TheFuture Inc.
- Emerson Electric
- Enbridge Gas Distribution Inc.
- Energy Efficiency Specialists Blogspot
- EnergySolutions
- Enersave
- Environmental Design / Build
- Feuerhelm Farms
- Finish Werks Custom Builders
- Florida Solar Energy Center

Call Attendees: Non-Members (2 of 3)

- Franklin Energy
- Freeborn-Mower Cooperative Services (FMCS)
- FSEnergy
- Global Green
- Green Compass Sustainability
- HDR Consulting LLC
- Home Performance LLC
- ICF International Inc.
- Insightful Healthy Homes Inc.
- Inspection Perfection (San Diego, CA)
- Jofforts Energy
- Johnson Controls Inc
- Kellen
- Kidd Panoscha Design
- Kriegh Architects
- LEENA Labs
- Leidos
- LexTM3
- McConnell Valdés
- Menlo Spark
- Minnesota Department of Commerce
- Minnesota Technical Assistance Program (MnTAP)
- NANA Regional Corporation
- NORESKO, LLC
- Northwest Energy Efficiency Alliance (NEEA)

Call Attendees: Non-Members (3 of 3)

- New York State Division of Housing and Community Renewal
- Ontario Ministry of Energy
- People's Self Help Housing
- PlugInConnect
- Power Integrations, Inc.
- Proctor Engineering Group
- PV Blue
- Quadlogic Controls Corporation
- RESNET
- Rheem Manufacturing
- Rhode Island Housing
- Seattle City Light
- Snohomish County, WA
- Southern Company Services, Inc.
- Southwest Energy Efficiency Project
- The South Central Partnership for Energy Efficiency as a Resource (SPEER)
- Third Rail Technologies
- U.S. Department of Housing and Urban Development (HUD)
- University of Minnesota - Center for Sustainable Building Research
- US EPA Combined Heat and Power (CHP) Partnership
- Utah Governor's Office of Energy Development
- Waite & Associates

Opening Poll #1

- Which best describes your organization's experience with residential energy storage?
 - Limited experience/familiarity – **52%**
 - Some experience/familiarity – **26%**
 - No experience/familiarity – **15%**
 - Very experienced/familiar – **6%**
 - Not applicable – **1%**

Closing Poll

- After today's call, what will you do?
 - Seek out additional information on one or more of the ideas – **68%**
 - Consider implementing one or more of the ideas discussed – **20%**
 - Make no changes to your current approach – **12%**
 - Other (please explain) – **0%**